# *Considering uncertainty in multi-objective spatial prioritization for California's agriculture, biodiversity, and water resources*

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**With Rodd Kelsey, Stacie Wolny, Adrian Vogl, Abby Hart, Scott Butterfield**

Stanford | Water in the West

The Nature Conservancy

natural capital PROJECT

# Outline

- Brief background on San Joaquin Valley ag and water
- Overview of late-stage project
- Discussion of uncertainties and options for treating them
- Connecting to other efforts

# Fast facts for context – San Joaquin Valley ag is big and small at the same time

- ~5M irrigated acres total (~2M ha)

- SJV Ag Revenue: ~$15 – $20 billion
- CA Ag Revenue: $45 – $50 billion
- CA GDP: ~$2.5 trillion

- Direct food production revenue still only 12% of SJV economy, 13% employment, 10% of GDP
  - (revenue nearly doubles if include food processing)

Hanak et al 2017

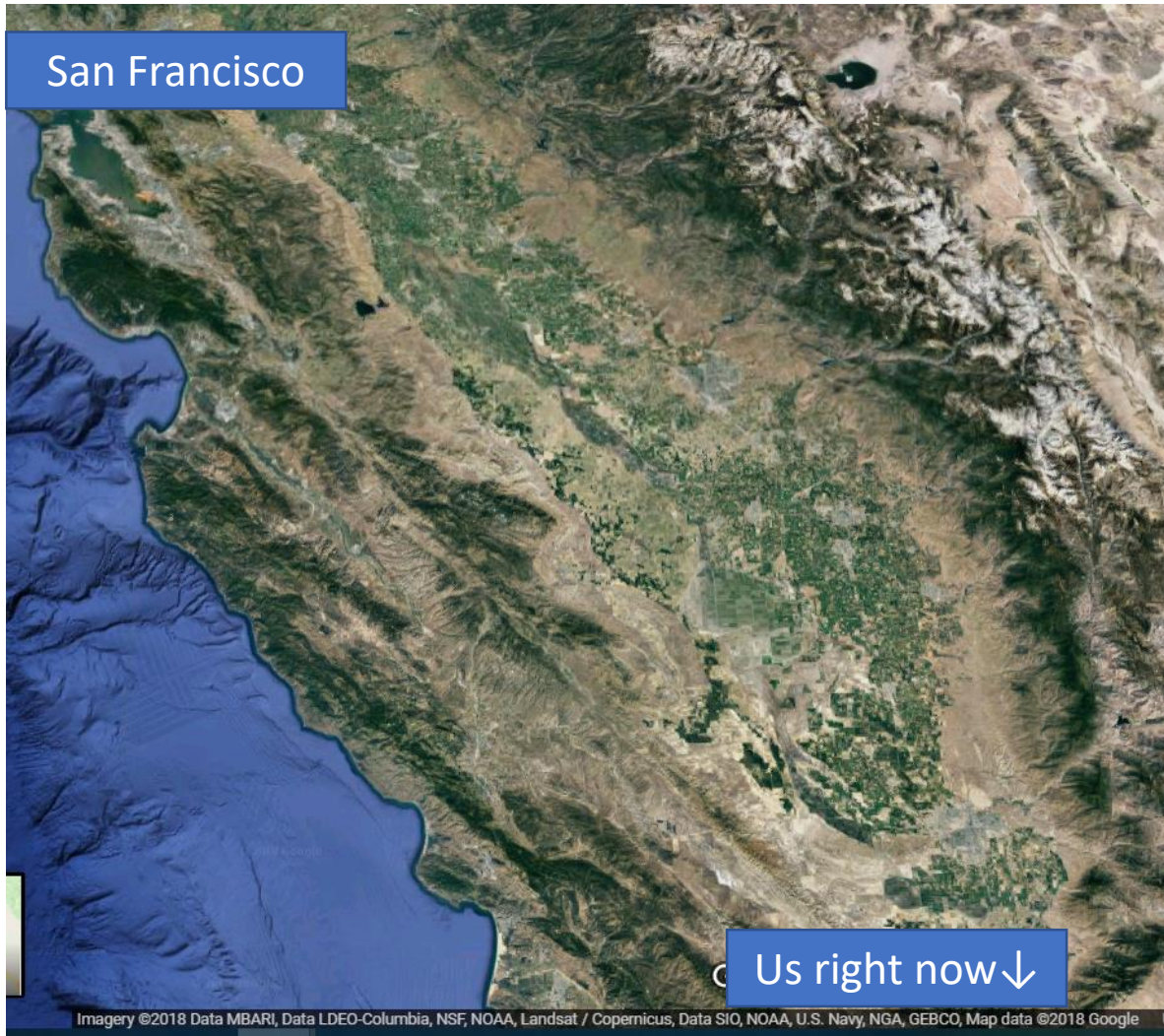
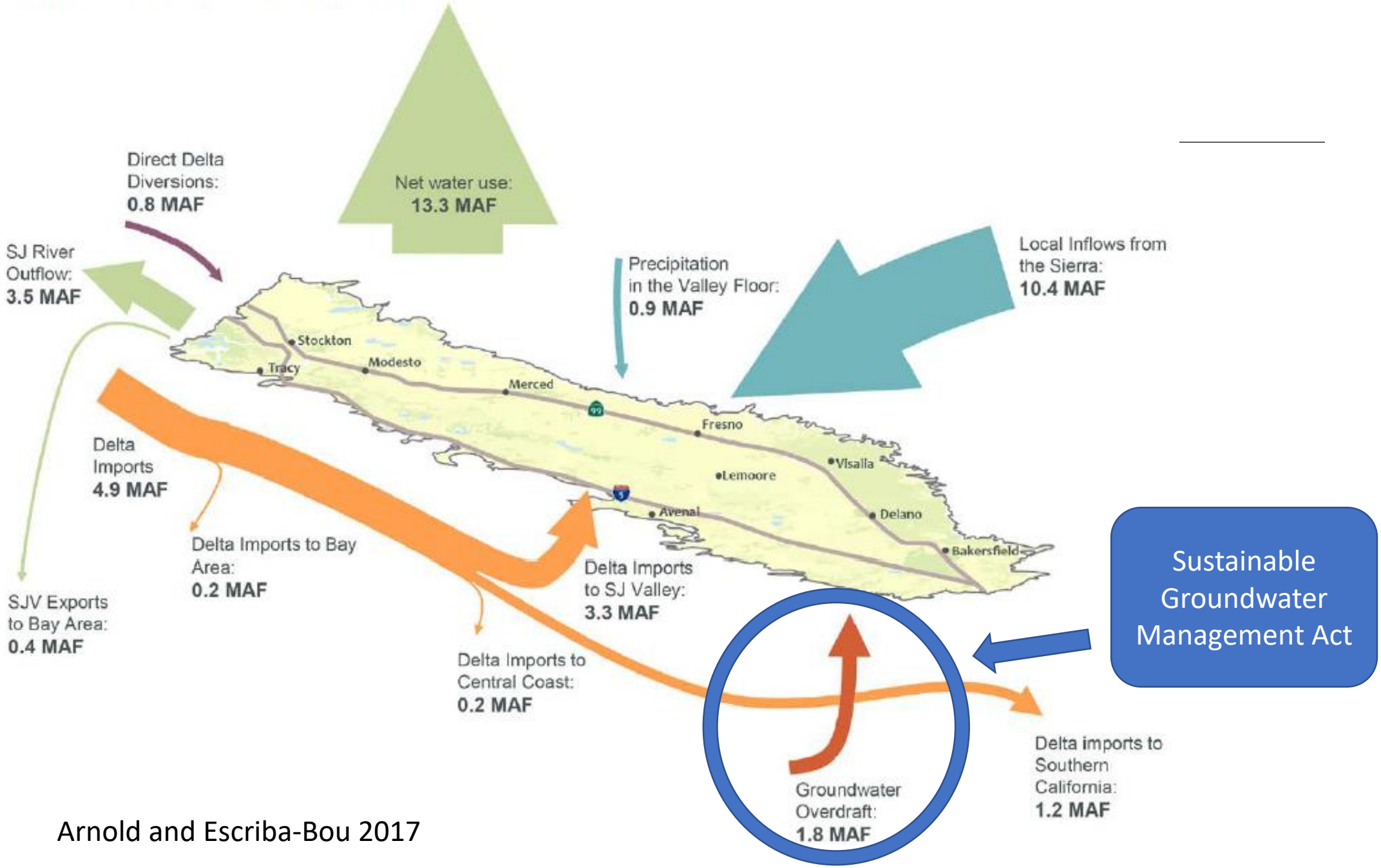


FIGURE A16
Average water balance in the San Joaquin Valley, 1986–2015




Arnold and Escriba-Bou 2017

# Historical land use has dramatically altered the landscape at the expense of biodiversity

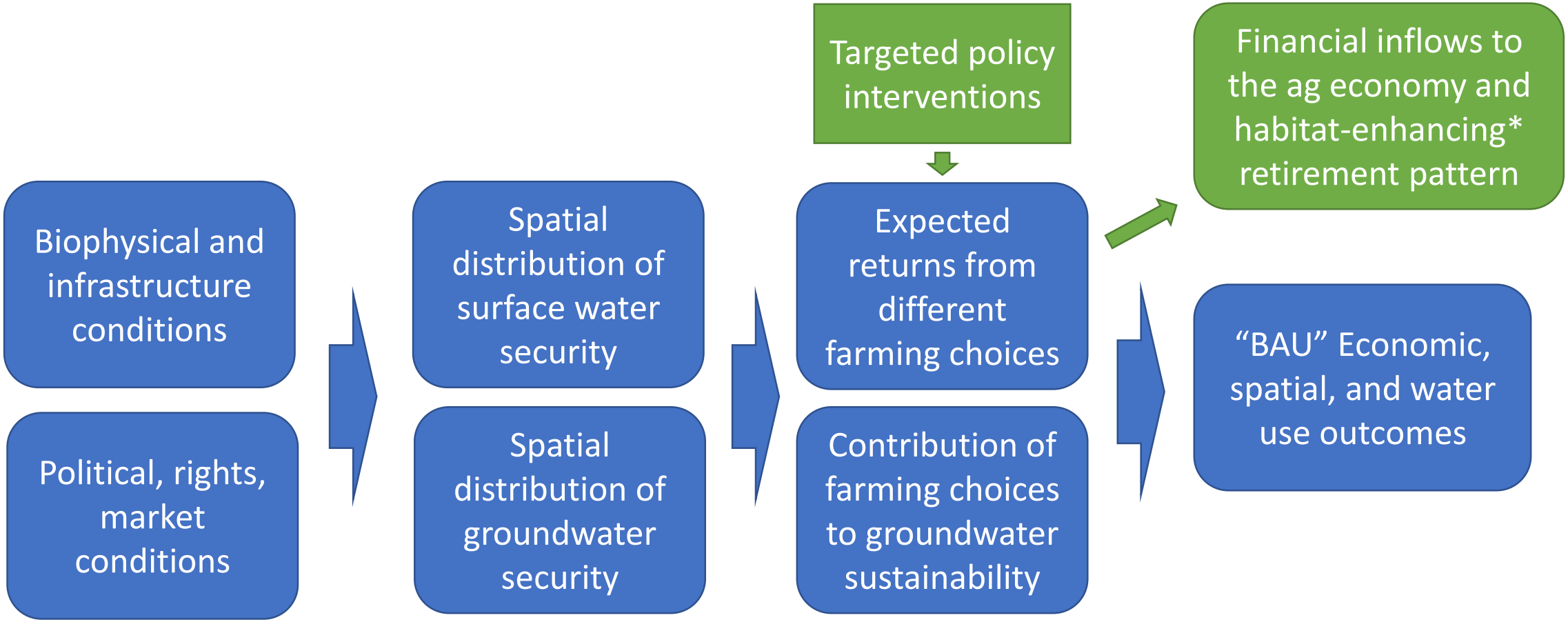
- Over 95% of the natural grasslands, scrublands, wetlands, and riparian forests have been lost
- Also, chronic underdelivery of CVPIA refuge water

One of the the highest densities of federally endangered species in the U.S.

# Can we achieve water and habitat goals while minimizing additional impact to the ag economy?

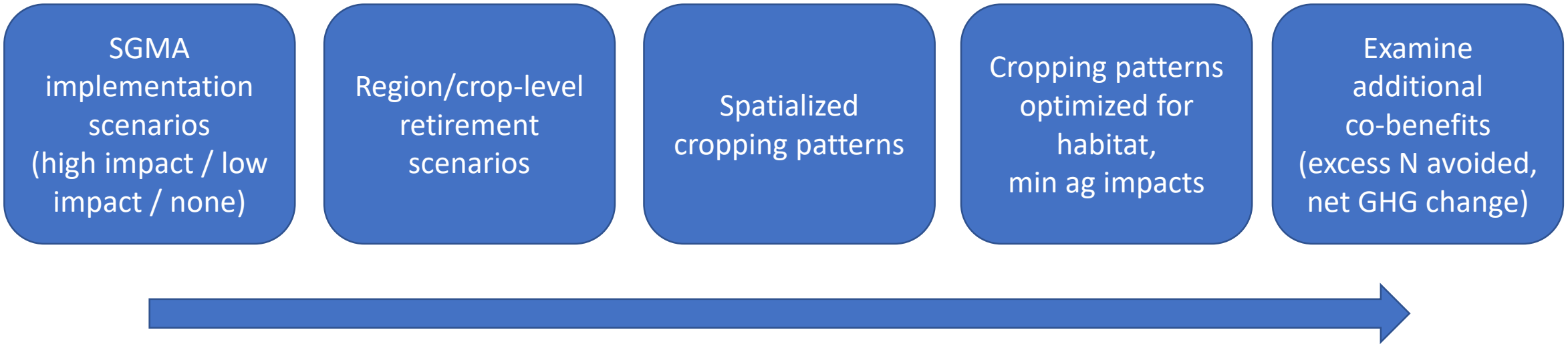
- Build picture of plausible BAU retirement under SGMA
- Assess opportunities to move or enhance that retirement, for additional water and desert habitat
- Build picture of co-benefits that may provide payment opportunities

# Thinking within the context of what's driving change




*Or more broadly: Environmental and health outcomes

# High-level workflow: Many steps of analysis, each laden with assumptions (that we should explore!)




- Mix of contracted models, hand-developed models, propriety and open-source

# We contract ERA's SWAP-RTS model to produce retirement estimates by crop and subbasin for SGMA

Simulates farmer decisions, water availability, and market dynamics

Complete coverage of California's irrigated agriculture and complex regulatory environment

Includes all major crops and federal, state, and local water sources

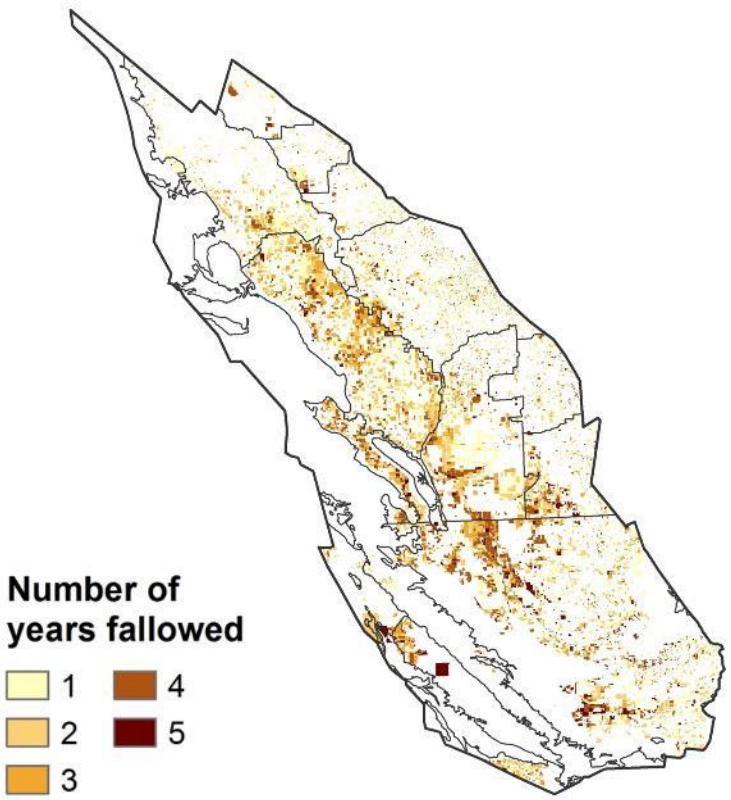
Powered by proprietary agricultural, hydrologic, and economic data

Gets us areas by crop category and subbasin + revenue, net revenue, applied water, ET of AW

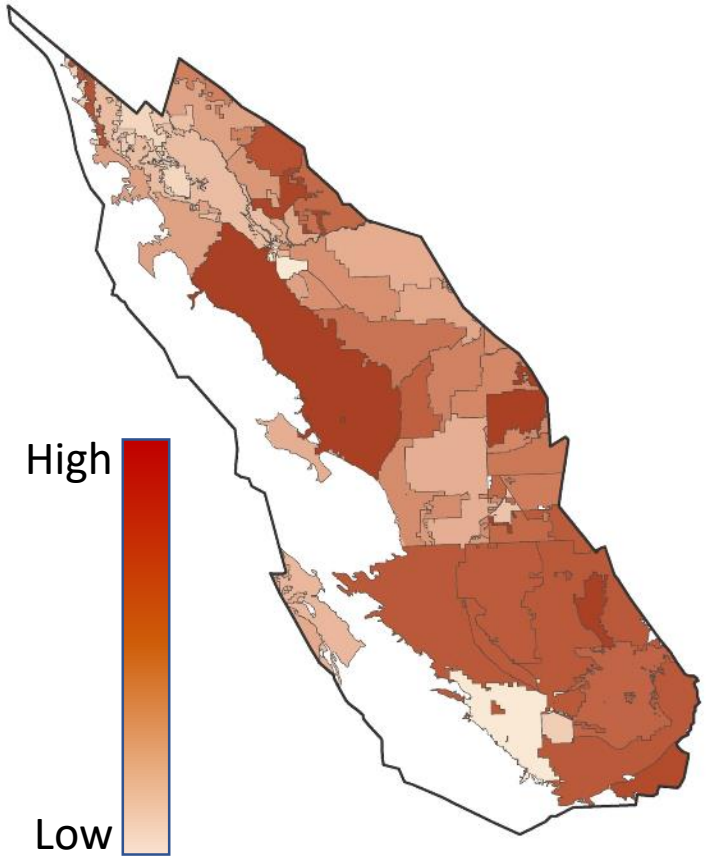
http://swapmodel.com/

# Where will retired acres most likely end up?

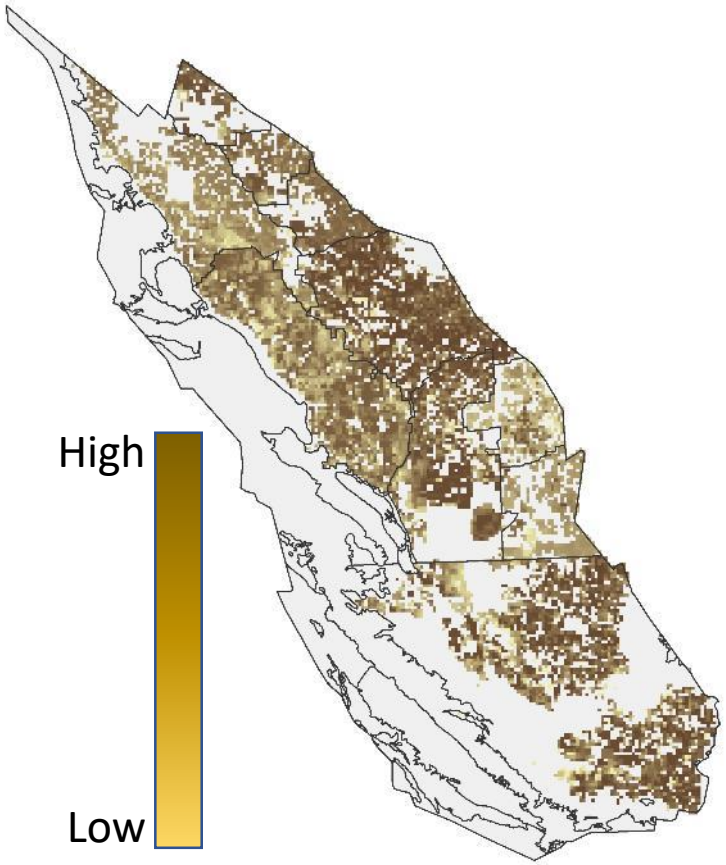
Surface water and soil data




Groundwater Dependence

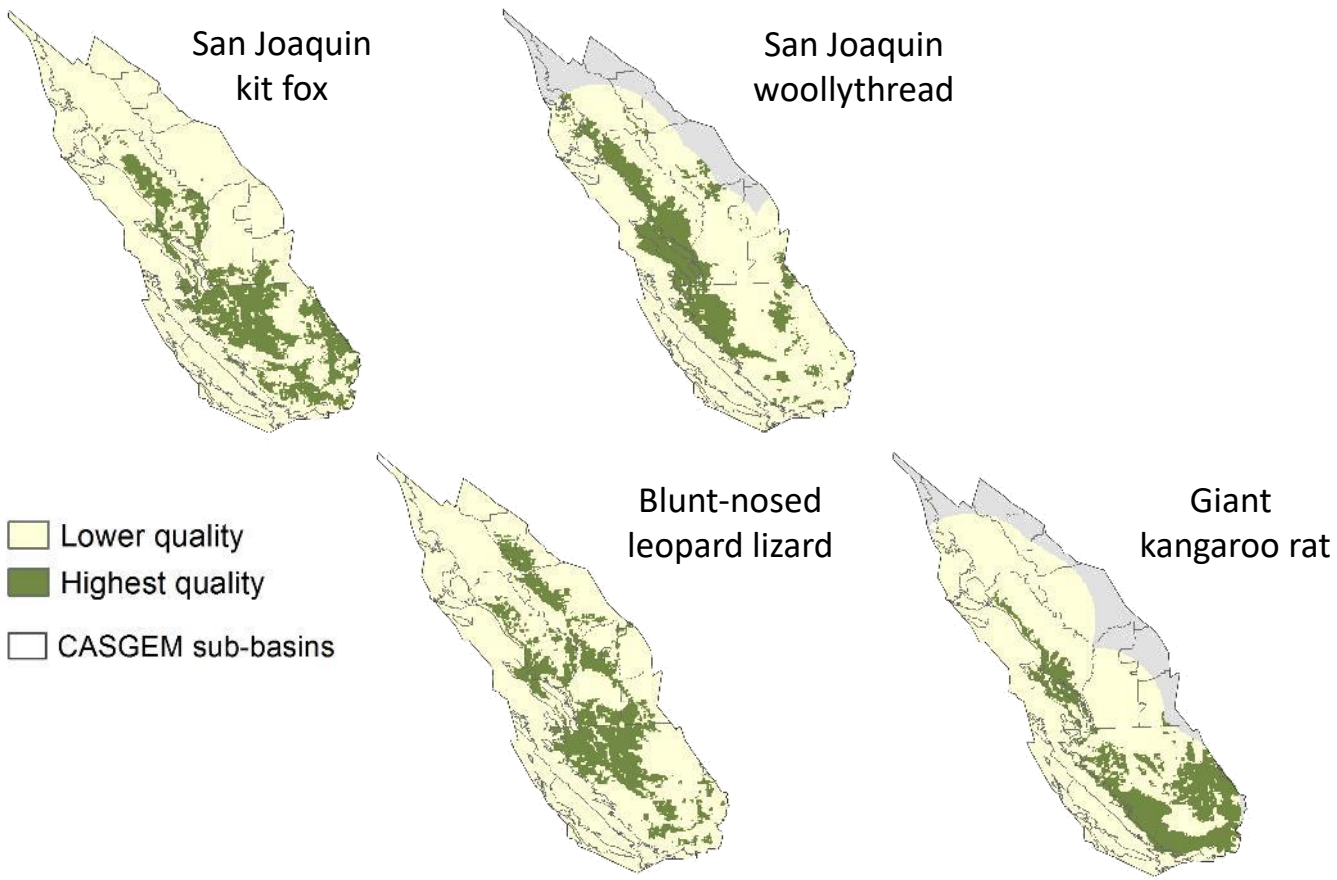



Agricultural Sustainability Index

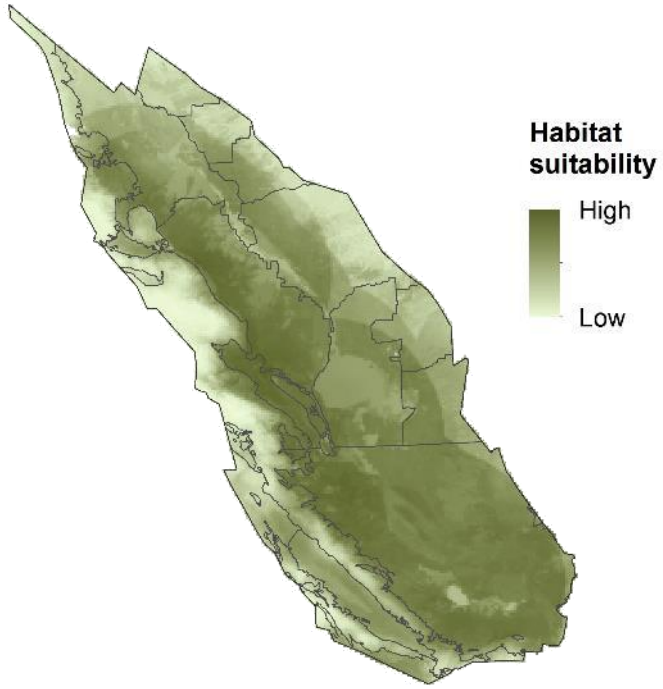


# Habitat maps from MaxEnt-based species distribution models

Minimum area of highest quality habitat per species

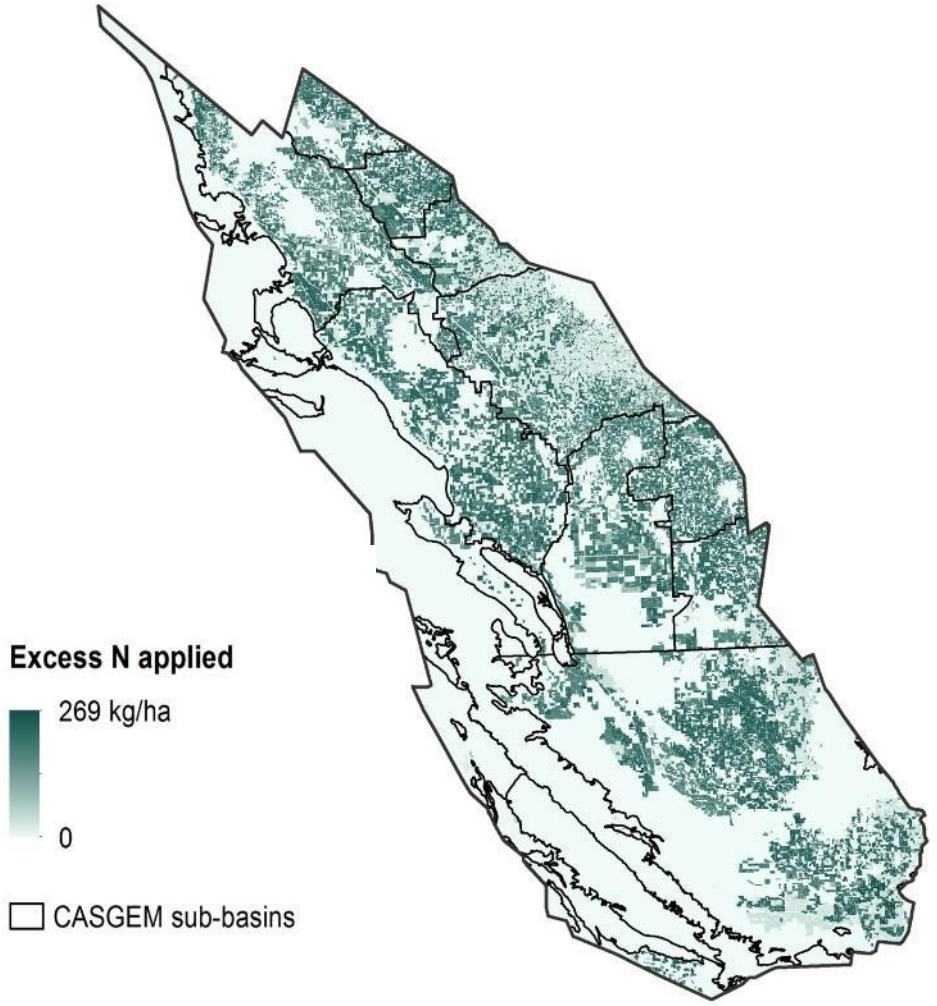



High overall habitat value: Habitat Suitability Index



# Excess nitrogen estimates compiled from California Nitrogen Assessment

- Excess nitrogen applied (kg/ha)
- Vulnerability to Nitrates
  - Population size
  - Groundwater for drinking
  - Existing concentration



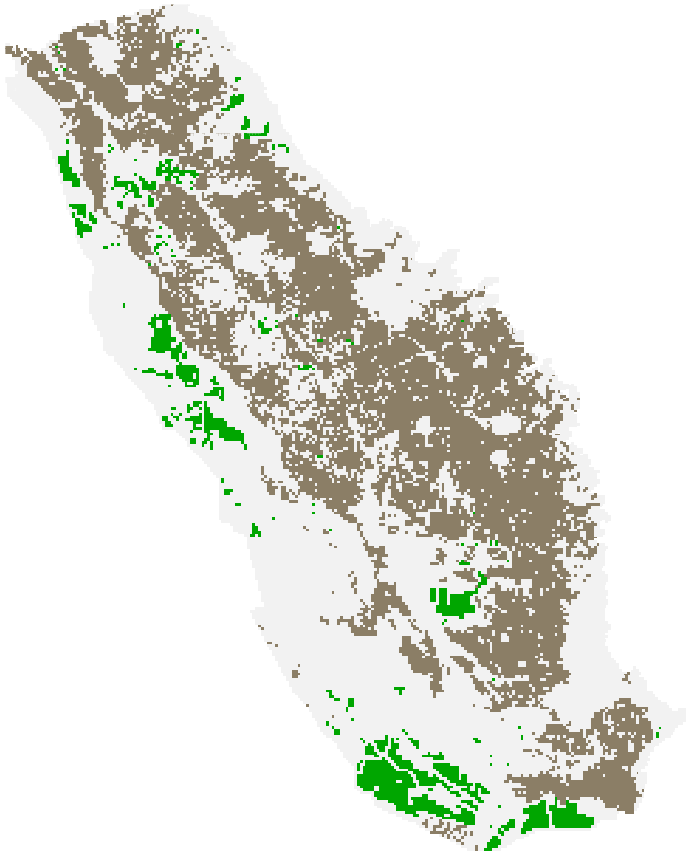
# Avoided GHG estimates built off other work


Modified COMET / DayCent runs for net GHG emissions + Simplified LUCAS

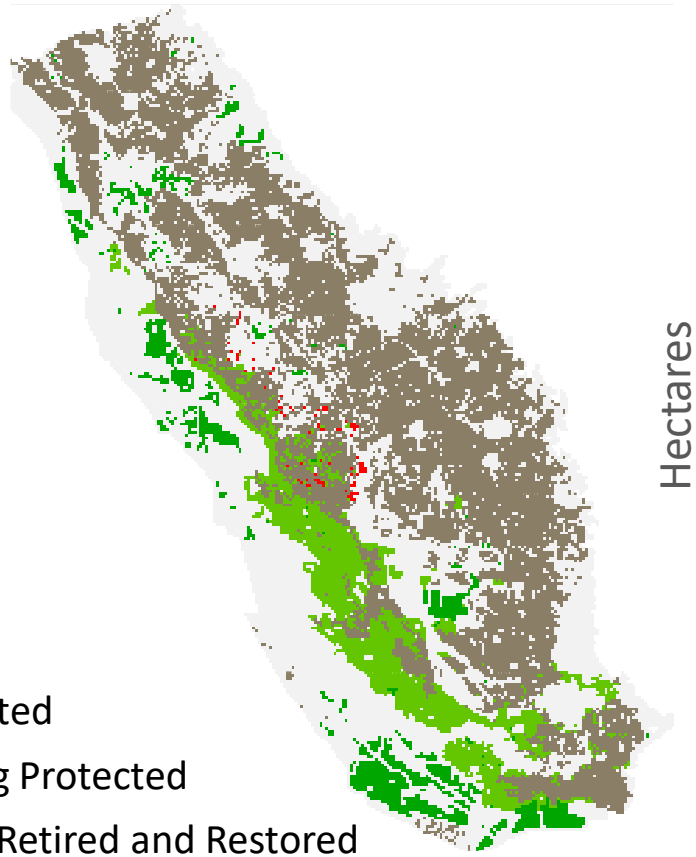
Sleeter, Benjamin M., et al. "Effects of contemporary land-use and land-cover change on the carbon balance of terrestrial ecosystems in the United States." *Environmental Research Letters* 13.4 (2018): 045006.

# Spatial view of strategic retirement

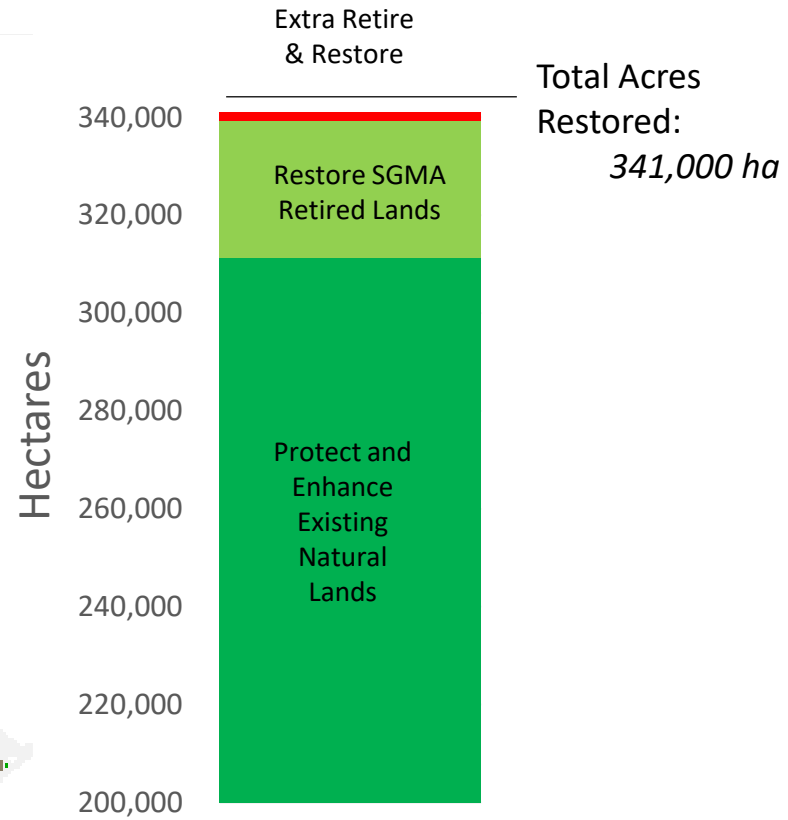
## Current Day



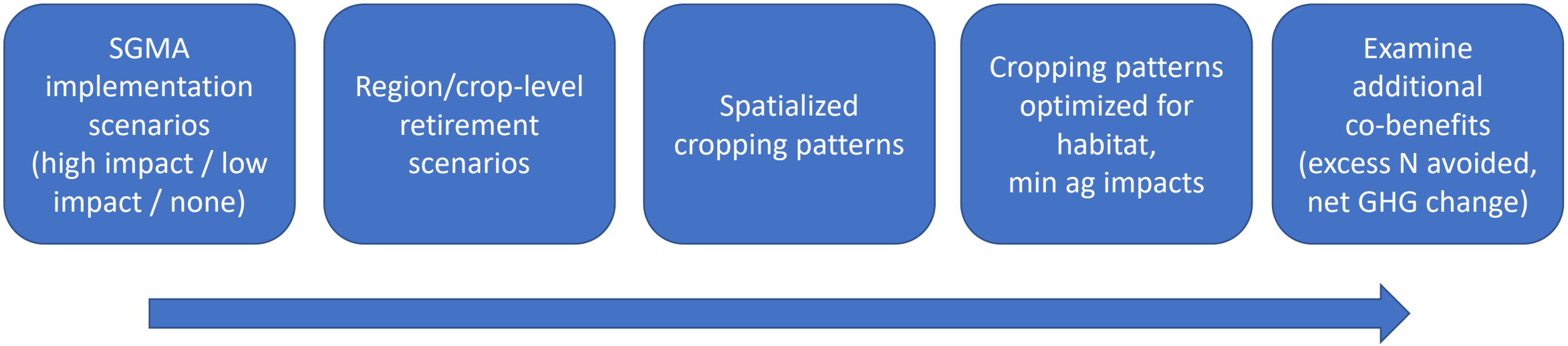
## Strategic Restoration



Cultivated
Existing Protected
SGMA Retired and Restored
Extra SLRR



# Back to the uncertainties…



# A “lite” uncertainty matrix*

| Uncertainty | How treated | What not treated | Is that ok? |
|---|---|---|---|
| Future water availability | Supply augmentation and policy explored as spanning scenarios | Default uses “a” climate scenario | Sort of – some fungibility between climate and water for purposes of the analysis |
| Downscaling of cropping patterns – where do things go? | Explore weighting of spatial drivers in a “rule-based” retirement approach. **Plus bounding.** | Explicit representation of agent-decisionmaking | Probably ok for assessing robustness of narrative – NOT ok for operational work |
| Downscaling of cropping patterns – what crop categories? | Use higher aggregated categories (tree vs field vs row) – but derive ranges from constituent categories | Balancing in response to basin-wide demand (yes to mean, no to ranges) | Not bad! |

*Walker et al 2003; Refsgaard 2007

# A “lite” uncertainty matrix – continued

| Uncertainty | How treated | What not treated | Is that ok? |
|---|---|---|---|
| Spatial scale of trading allowed? | Formulate basin-wide uncertainty in trading rules as constraints on optimization | Intra-subbasin trading assumptions | Yes, b/c bounds narrative – can build in actual policy in an operational application |
| Spatial scale for considering connectivity | Run optimizer over multiple resolutions and different base LULC aggregation methods | Migration corridors, proximity | Pretty good – would be nicer to consider patch size, climate migration |
| Carbon impacts of GHG – dependence on perennial turnover assumptions | Run for climate-oriented and historical turnover | Path-dependence of when comes in and out of production | Probably ok for assessing robustness of narrative – NOT ok for operational work |
| Metrics – what “speaks” to ag economy concerns? | Re-run with net revenue, ranges on non-ag land | Labor, incidence, capital costs | No for numbers, yes for illuminating key consideration |

# Long-term: Filling in a matrix of land use action and multiple objectives to support adaptation

| | Water savings | Economic returns to ag (economy-wide + distributional impacts) | Habitat gains and cross-payments | Carbon gains and cross-payments | Pollutant Exposure / Health |
|---|---|---|---|---|---|
| Permanent retirement | | | | | |
| Desert Restoration | | | | | |
| Wetland Restoration | | | | | |
| Temporary fallowing for dynamic habitat | | | | | |
| On-Farm recharge | | | | | |
| Dedicated recharge | | | | | |
| Crop switching | | | | | |
| Solar | | | | | |
| Urban development | | | | | |

# Multiple groups do similar but distinct efforts

- All of these groups involved in water, ag, habitat
- Some strengths and some weaknesses for each
- Also coordinating for synergies
- More broadly, want to connect beyond water and habitat

Point Blue™

EDF
ENVIRONMENTAL DEFENSE FUND
Finding the ways that work

The Nature Conservancy

American Farmland Trust
Saving the Land that Sustains Us

Conservation Biology Institute

# Things we should be doing

- Exploring better integration with water resources planning
  - Infra and allocation
  - Climate/hydrology
- Distributional impacts and endogeneity of responses
  - (Ie, not just farmers)
- Connecting to land use planners
  - Documented they don’t talk that well, but things are improving
- Careful tracking of narrative vs planning vs operational analysis

# Thanks!

Questions/thoughts:
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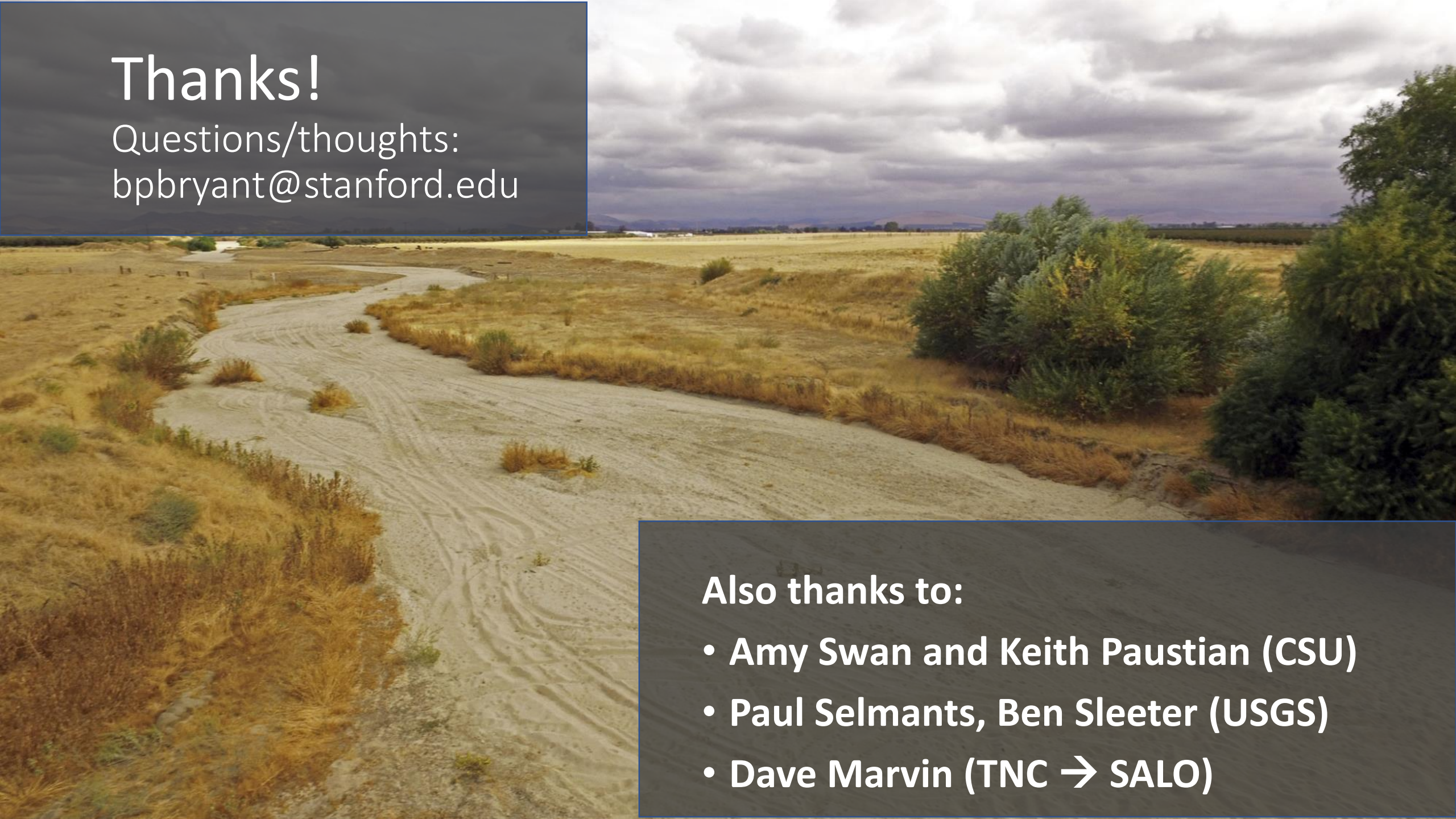

**Also thanks to:**

- **Amy Swan and Keith Paustian (CSU)**
- **Paul Selmants, Ben Sleeter (USGS)**
- **Dave Marvin (TNC → SALO)**

**UNRELATED PLUG:**

# Fresh special issue on uncertainty in ecosystem services modeling

## Demonstrating transparent, feasible, and useful uncertainty assessment in ecosystem services modeling.

Edited by Benjamin Bryant, Mark Borsuk, Simon Willcock, Catharina Schulp, Kirsten Oleson
Volume 33, Part B, Pages 103-246 (October 2018)

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https://www.sciencedirect.com/journal/ecosystem-services/vol/33/part/PB

# Some impacts are ambiguous (= opportunity for science or analysis)

- Air quality: Increased wind-driven erosion of unprotected soils) vs avoided inputs
  - ➔ Active restoration important
- Scattered retirement as weed/pest source vs habitat as “pest” source
- Recharge: Dilution of nitrate vs avoidance of high nitrate areas
  - Give groundwater water over to ag??
- Equity in water – Is land management really a sufficiently effective entry point?